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Technical Paper 334

DEPARTMENT OF THE INTERIOR
HUBERT WORK, SECRETARY
BUREAU OF MINES
H. FOSTER BAIN, DIRECTOR

MINE RESCUE STANDARDS

A TENTATIVE STUDY

PREPARED BY A COMMITTEE APPOINTED
AT THE INTERNATIONAL MINE-RESCUE
STANDARDIZATION CONFERENCE
SEPTEMBER, 1921

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MINE RESCUE STANDARDS: A TENTATIVE STUDY.

Prepared by a Committee Appointed at the International Mine Rescue Standardization Conference, September, 1921.

INTRODUCTION.

1. A standardized procedure in mine rescue work after mine explosions and fires has long been needed, and the desirability of a certain degree of standardization of mine rescue apparatus has been generally recognized. Therefore, when the Hon. William Sloan, Minister of Mines of British Columbia, proposed that the United States Bureau of Mines and the Department of Mines of British Columbia confer on the subject, Dr. H. Foster Bain, Director of the Bureau of Mines, welcomed the proposal and asked the chief mining engineer, the writer of this introduction, to organize the conference and to act as temporary chairman. Then it was decided to make the conference of international scope and the bureau issued invitations to the mining departments of various countries, Great Britain, Canada, France, and Belgium, to send representatives to a conference at the time of the International First-Aid and Mine Rescue Meet held under the auspices of the U. S. Bureau of Mines at St. Louis, Mo., September 1 to 3, 1921.

2. As many of the States and Provinces had mine rescue organizations, invitations were issued to the mining departments of the various States of the United States and of the Provinces of the Dominion of Canada; also, as the mine rescue organizations of various mining companies were equally concerned, invitations were sent to them.

3. The conference proved a success. Great Britain was represented by Lt. Col. J. A. S. Ritson, Canada by Duncan McDonald, British Columbia by Robert Strachan. In addition to its distinguished foreign delegates, the conference was attended by well-known mine operators, State inspectors, mine-safety engineers, and experienced mine rescue men from most of the principal mining districts of the United States as well as by the director and members of the staff of the U. S. Bureau of Mines. Numerous valuable

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papers presented before it were published in mining journals. The following resolution was unanimously adopted:

Whereas it is the sense of this conference that it is highly important to advance the art of mine rescue work by a certain degree of standardization of mine rescue methods and the use of apparatus and appliances so that improvements may be effected along lines which will guide and assist those engaged or concerned in mine rescue work.

Therefore, Be it resolved that a committee be designated by the chairman, at his convenience, that will at some later date or dates, as may seem expedient, make a report or reports under the auspices of the Bureau of Mines, which will be made public, and that such committee shall continue its work until there shall be a future International Mine Rescue Conference called or held under the auspices of the United States Bureau of Mines.

4. In accordance with this resolution a committee and subcommittees were appointed as follows:

PERSONNEL OF MINE RESCUE STANDARDIZATION COMMITTEE AS DIVIDED INTO SUBCOMMITTEES.

George S. Rice, Washington, D. C., general chairman.
J. W. Paul, Pittsburgh, Pa., general secretary.

SUBCOMMITTEE No. 1.

INTERNATIONAL MINE RESCUE STANDARDS.

This committee will act as liaison committee to representatives of other countries than the United States and additional names may be added.

Lieut. Col. J. A. S. Ritson, Great Britian, chairman.
Robert Strachan, Canada.
J. W. Paul, Pittsburgh, Pa., U. S. A., secretary.

SUBCOMMITTEE No. 2.

RESCUE APPARATUS REQUIREMENTS AND TESTS FOR PERMISSIBILITY.

D. J. Parker, Pittsburgh, Pa., chairman.
J. E. Struble, Connellesville, Pa.
Ed. Williams, Johnstown, Pa.
C. J. Brehm, Oliver, Pa.

SUBCOMMITTEE No. 3

PHYSIOLOGICAL EFFECTS IN USE OF MINE RESCUE APPARATUS, AND METHODS FOR DETECTING DANGEROUS GASES.

Dr. R. R. Sayers, Washington, D. C., chairman.
Dr. A. F. Knoefel, Terre Haute, Ind.
Dr. Yandell Henderson, New Haven, Conn.
A. C. Fieldner, Pittsburgh, Pa.

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SUBCOMMITTEE No. 4

REGULATIONS FOR USE OF MINE RESCUE APPARATUS IN COAL MINES.

Robert Medill, Springfield, Ill., chairman.
C. A. Herbert, Vincennes, Ind., secretary.
a. 1. Flat coal beds—
E. H. Denny Pittsburgh, Pa.
Robert Lilly, West Virginia.
b. 2. Pitching coal beds—
J. J. Forbes, Birmingham, Ala.
J. J. Corey, Coos Bay, Oreg.

SUBCOMMITTEE No. 5.

REGULATIONS FOR USE OF MINE RESCUE APPARATUS IN METAL MINES.

D. Harrington, Denver, Colo., chairman.
H. J. Rahilly, Butte, Mont. (copper).
George Martinson, Hibbing, Minn. (iron).
Orr Woodburn, Globe, Ariz. (copper).
H. M. Woltlin, San Francisco, Calif. (gold and silver).

5. Members of the subcommittees held a preliminary meeting at Pittsburgh, Pa., on September 5 to 7, 1921, when the duties and the scope of work of each subcommittee were determined as follows:

SCOPE OF SUBCOMMITTEES.

SUBCOMMITTEE No. 1.

INTERNATIONAL STANDARDS.

a. The committee shall collect and disseminate information to the other subcommittees and furnish information to the foreign members or representatives of the committee.

b. The committee shall furnish the foreign members of the committee a list and facts regarding the nature of any problems on which any of the subcommittees may desire assistance or an expression of opinion.

c. The committee shall submit to the proper officials of the respective countries represented on the committee the result of recommendations made by the various committees.

d. The committee shall act as liaison between the various committees and the foreign members of committee No. 1 on all matters clearing through the secretary.

SUBCOMMITTEE No. 2.

RESCUE APPARATUS TEST REQUIREMENTS.

a. To review test requirements of the Bureau of Mines and of Great Britian and any other countries that have test requirements for breathing apparatus, with a view to improving and standardizing tests for apparatus as far as the state of the art will permit.

b. To determine the tests necessary to be applied immediately prior to the actual use of breathing apparatus in service and to specify how frequently the ap-

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paratus should be tested in order that it may be maintained in proper condition for service.

c. To specify the methods most suitable for storing and housing the apparatus so as to reduce deterioration.

SUBCOMMITTEE No. 3.

PHYSIOLOGICAL EFFECTS IN USE OF MINE RESCUE APPARATUS AND METHODS FOR DETENTION OF DANGEROUS GASES.

a. The physiological requirements for breathing apparatus.

b. To prescribe a method whereby a local physician may determine the fitness of men to use breathing apparatus just prior to their use in service or initial training.

c. To prescribe a method that may be used by a captain of the rescue crew to determine the fitness of men to use breathing apparatus just prior to their use in service.

d. The physiological effects of gases encountered in mines.

e. Appliances and methods for the quick determination of gases encountered in mines.

SUBCOMMITTEE No. 4.

REGULATIONS FOR USE OF MINE RESCUE APPARATUS IN COAL MINES.

1. In flat beds.
2. In pitching beds.

a. Organization and equipment at mines with reference to possible explosion and fires; notification of Government or State officials and mine rescue crews of explosions or fires endangering life. (Also notifying officials of connecting mines.)

b. Organization after explosions or fires, including selection of person to be in responsible charge according to legal conditions or through voluntary agreement of owners and State officials.

c. Duties of captain and members of rescue crews.

d. Conditions under which breathing apparatus of permissible type may be used and when in entering and exploring coal mines.

e. Application of tests of breathing apparatus suitable to that apparatus in accordance with specifications laid down by subcommittee No. 3.

f. Testing of physiological condition of men under provisions laid down by subcommittee No. 3.

g. Procedure in entering mines by shafts, by slopes, and by drifts.

h. Accessory apparatus and supplies that should be provided before and in connection with coal-mine recovery work.

i. Procedure in the establishment of fresh-air bases and limitations in reventilating former air circuits, in view of the danger of igniting fire damp from fires in the circuit.

j. Maximum distance to which men in apparatus should explore beyond fresh-air bases under conditions in which live men may be found, in view of falls and obstructions.

k. In pitching beds the maximum vertical height to which men in apparatus should climb—

1. On an incline.
2. By stairs or ladders plus horizontal distance to incline or raise.

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SUBCOMMITTEE No. 5.

REGULATIONS FOR USE OF MINE RESCUE APPARATUS IN METAL MINES.

a. Mine rescue equipment at surface prior to emergency, including housing (station, car, etc.), apparatus, lamps, rescue truck, oxygen cylinders, and pumps, etc.

b. Mine rescue organizations prior to emergency, including safety men, trainer or person in charge of rescue work, equipment and names and addresses of mine rescue men and others, also measures taken beforehand to denote definitely specific duties of employees at time of fire, etc.

c. Preliminary measures for prompt notification of Government, State, and company officials at outbreak of fire, etc., with simultaneous notification of mine rescue crews, doctors, ambulances, adjoining or connecting mines, etc.

d. Organization at outbreak of fire or similar emergency. Placing some responsible person in charge who shall effect prompt organization of rescue and relief work, including assembling of apparatus crews, establishing bases for repair of apparatus, taking care of dead and injured, etc.

e. Duties of captain and members of rescue teams in times of emergency.

f. Placing of competent man or men in charge of assembling and repair of apparatus and of application of tests of apparatus as laid down by subcommittee No. 2.

g. Physical examination of members of mine rescue crews as laid down by subcommittee No. 3.

6. After the Pittsburgh conference various subcommittees met from time to time but, because of the great difficulty of assembling, the committee as a whole held no meetings but handled the various subjects and questions of approval by correspondence. The reports of the various subcommittees on standards and rules of procedure following mine explosions and fires are as given hereinafter. Owing to the difficulties of communication with foreign members of subcommittee No. 1, that committee did not render a separate report; but Mr. J. W. Paul, secretary of the subcommittee, who has had a wide experience in rescue work and in designing rescue apparatus, has reviewed and in principal approved the subcommittee reports.

7. The committee as a whole desires to have it emphasized that these standards and rules are not in any sense final but are tentative and subject to further consideration, amendment, and correction. Accordingly, all persons with a practical knowledge of the subject are invited to send constructive comments to any member of the committee or to the secretary.

8. Should a future international mine rescue conference be held, these standards and rules and amendments will be submitted for consideration at such conference.

GEORGE S. RICE, *Chairman.*
Bureau of Mines, Washington, D. C.

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9. This subcommittee has reviewed the requirements for approval of mine rescue apparatus by the United States Bureau of Mines, as comprised in general regulations of July 30, 1920, in pursuance of establishing a list of permissible self-contained mine rescue breathing apparatus," and similar requirements of the British Government comprised in general regulations of July 30, 1920, in pursuance of section 86 of the British coal mines act, 1911. In accordance with those governmental requirements, this subcommittee recommends the following-named requirements for the approval of mine rescue apparatus for use in irrespirable gases in mines:

10. The amount of oxygen or air supplied by the apparatus should meet the needs of the wearer at all times. In every breathing apparatus which is arranged to give a uniform delivery of oxygen the reducing valve should be so adjusted as to supply not less than 2 liters of oxygen a minute.

11. Regenerating material, if used, should absorb from the expired air carbon dioxide to the extent that not more than 2½ per cent will at any time be present in the inspired air. The average carbon dioxide content in expired air should not exceed 1 per cent during any two-hour test period.

12. Apparatus should be free from mechanical obstructions in order that the wearer may breathe freely at all times. A measure of this freedom from mechanical obstruction is the resistance of the apparatus as a whole to the passage of air through the circulatory system. The highest resistance of an apparatus should not exceed 3 inches, water gauge.

13. The temperature of the inspired air should not be more than 36° F. (20° C.) in excess of the temperature of the surrounding atmosphere.

14. The apparatus should be durable in construction, and all vital parts should be so protected as to prevent material damage or wear of the apparatus during period of tests.

15. All rescue apparatus should be provided with a by-pass valve which shall permit a free flow of oxygen or air from oxygen or air container to the circulatory system of the apparatus, independent of the reducing valve and the main closing valve.

16. Apparatus should be designed to meet the needs of the wearer for a period of not less than two hours when worn in irrespirable

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atmospheres without recharging. However, this committee recognizes the value which apparatus of a less oxygen capacity, such as the so-called "half-hour type," may have for certain auxiliary purposes in rescue work underground, and does not recommend that their use as auxiliary to the two-hour apparatus be barred, provided they answer these general requirements except oxygen capacity and regenerator capacity.

17. Apparatus should be of design using a mouth-breathing device or other face attachment, which when properly adjusted to the face of the wearer, has a capacity of not more than 250 c. c. of dead space inside it, including any tubes or connections attached thereto up to the inhalation and exhalation valves.

18. Apparatus, complete with headpiece and fully charged, should not weigh more than 40 pounds. The lightest weight possible compatible with safety and durability of construction is desirable.

19. The mechanical construction of the apparatus should be such that every part can be tested, inspected, and repaired by persons skilled in such work, and all parts that require sterilizing should be readily accessible.

20. All parts of the apparatus subject to or liable to be subjected to pressure in excess of 5 pounds per square inch should be of such construction or equipped with such safety devices as will insure the safety of the wearer.

21. In apparatus equipped with breathing bag or bags or their equivalent, the inhalation and exhalation compartments should have a combined capacity of at least 8 liters; provided, however, that if a breathing bag with single compartment only is used it should have a capacity of not less than 5 liters.

22. Apparatus should not have in its circulatory system any zone of constant negative pressure.

23. Apparatus should be provided with a release valve, operated by hand or automatically, placed at some point in the circulatory system of the apparatus for the purpose of releasing to the outside air, when desirable, a portion of the air in that system.

24. If apparatus is equipped with high-pressure oxygen cylinders, such cylinders should be subjected to any governmental requirements for safety. If a safety cap is attached to the closing valve of the apparatus cylinder or cylinders containing high-pressure oxygen, such safety cap should, in addition to the disk ordinarily provided, be filled with a metal fusing at a temperature of approximately 94° C., and such fusible metal should not extrude from the safety cap under a pressure of 150 atmospheres.

25. Every apparatus should be equipped with a gauge for recording time or the pressure of the oxygen supply; this gauge should be of tested accuracy and should be placed on the apparatus at a point

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where it can be easily read by the wearer of the apparatus. The flow of oxygen to the gauge should be controlled by a gauge valve placed so that it can be readily manipulated by the wearer and is independent of the circulatory system of the apparatus.

26. When the oxygen supply of the apparatus is controlled by automatic devices, such devices should readily adjust themselves to the needs of the wearer.

27. The main closing valve of the high-pressure oxygen cylinder or cylinders should be so constructed that the apparatus wearer can not screw the valve stem entirely out of the valve. The main closing valve should also be provided with devices that will enable the apparatus wearer to lock the valve open.

28. Any apparatus equipped with a mouth-breathing device should be provided with an adequate saliva trap and nose clip.

29. Oxygen[1] used in breathing apparatus should be of not less than 98 per cent purity; impurity to consist of nitrogen only.

30. Before any apparatus is approved by any governmental agency this committee recommends that such apparatus be subjected to enough tests of sufficiently varied character to determine the adequacy and safety of the apparatus, as covered by the foregoing requirements.

31. Of equal importance with the selection of a suitable type of apparatus that meets the above-named requirements is the proper testing of apparatus immediately prior to its use in irrespirable atmospheres, to determine its condition for use in such atmospheres. Furthermore, the apparatus should be tested at regular intervals in order that it may be maintained in proper condition for emergency service. Tests of apparatus for air tightness and proper working condition necessarily vary with the particular apparatus used. However, the following tests will apply to a number of the present types of apparatus:

32. The contents of the apparatus bottle or cylinder should be tested by reading the gauge. Any moisture in the bottle should be removed by holding the charged bottle vertically, with closing valve down, then opening the main closing valve momentarily and quickly closing it.

33. The main closing valve on the oxygen bottle should be tested for leakage by immersing the bottle and valve in water; any bubbles of escaping air will show leakage. The main closing valve should then be capped with its metal cap, the main closing valve opened,

[1] Refers to compressed oxygen only; the subcommittee does not attempt to specify requirements for liquid oxygen or liquid air apparatus, as such apparatus is not now being used in the United States or Canada, although certain types have been approved for use by Great Britain.

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and the bottle again immersed in water; bubbles will show leakage around the packing gland and the stem of the valve.

34. If the reducing valve is of the automatic type, it should be tested with a special gauge to determine that it operates within required pressure limits, such limits differing with the type of apparatus. If the reducing valve is of the fixed-feed type, the flow of oxygen through the valve should be measured with a 3-liter bag or a flow meter.

35. If the air circulation in the apparatus is induced by an injector, this circulation should be measured with a bag of large capacity or a flow meter. All apparatus of the injector type should have a circulation of at least 75 liters a minute.

36. By admitting oxygen into the gauge and applying soapsuds with a brush to all high-pressure connections leakage of oxygen can be detected. If oxygen under high pressure is trapped between the gauge-closing valve and the gauge, a downward movement of the indicator hand of the pressure gauge will show leakage, either in the gauge or the connections.

37. Automatic-feed types of apparatus ordinarily have a safety valve for automatic release of any excess pressure that might develop on account of a failure of the reducing valve to function properly. The proper functioning of such safety valves can be tested by attaching a special pressure gauge and by manipulation of the reducing valve to allow oxygen to flow through the reducing valve at a pressure higher than ordinary until the blow-off point of the safety valve is reached.

38. Automatic-feed types of breathing apparatus ordinarily have an admission valve of some sort besides the main reducing valve. This admission valve can be tested for leakage by trapping oxygen between it and the reducing valve and observing whether the indicator hand on the pressure gauge remains stationary when all other connections involved have been tested for air-tightness. Proper functioning of the admission valve can be tested by hand manipulation or actual breathing from apparatus by wearer.

39. A regenerator, if used, should be tested for tightness at connections (by soapsuds and brush) and for resistance to air circulation. Resistance in the regenerator can be detected, after necessary connections to it have been made, by blowing with the breath into one connection and observing whether much physical effort, if any, is required to maintain air circulation.

40. A breathing bag, if used, should be tested for leakage by fully inflating the bag with air, blocking the opening to the bag, and then testing for leakage by use of brush and soapsuds.

41. Mouthpiece and attached inhalation and exhalation tubes should be tested for air-tightness and for proper functioning of in-

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halation and exhalation valves. These tests can be made by blowing in the various couplings while the parts are immersed in water. Valve leakage will be shown by bubbles.

42. A release valve, whether automatic or hand operated, can readily be tested for proper functioning by operating it by hand, if it is hand operated, or by applying excess air pressure to apparatus if the valve is automatically operated. Application of soapsuds will disclose leakage.

43. A nose clip, if used, should be tested by placing it in position on the apparatus wearer and having him attempt to inhale and exhale deeply through the nose. Such inhalation and exhalation should be impossible if the nose clip is tight.

44. The foregoing tests should be supplemented, before apparatus is worn underground, by wearing the apparatus for 5 minutes in a room filled with formaldehyde or ammonia fumes, or dense smoke. After wearing the apparatus thus for a 5-minute period during which the apparatus functions properly and there is no indication of fumes being present in the inhaled air, the wearer can be sure that his apparatus is in good working condition for performing work in poisonous gases and irrespirable air.

45. This committee vigorously condemns the so-called cigarette or cigar test—the use of a glowing cigarette or match end to detect oxygen leakage. Several serious accidents have happened during the progress of tests by such means, because apparatus parts were ignited through the rapid chemical action of free oxygen in the presence of flame.

46. Immersion of the apparatus as a whole in water has considerable advantage in disclosing the presence or absence of air leakage, particularly if the person making the test has had limited experience in apparatus testing. However, such a water test does not necessarily show the apparatus to be in proper condition in so far as the functioning of parts is concerned, and this committee recommends that the combination of leakage tests and of tests for functioning of all parts, as outlined in a general way above, be followed always.

47. The present types of oxygen breathing apparatus, largely because rubber seems indispensable in their construction, are peculiarly and unfortunately subject to more or less rapid physical deterioration unless cared for properly. Such deterioration is more rapid with some types of apparatus than others, but may become serious with any. Troubles due to deterioration can be lessened by providing adequate and proper storage facilities. Breathing apparatus should be protected against the sun, dust, steam, and hot water. All rubber parts should be kept, as far as possible, in a cool, moist atmosphere and in a darkened room—complete darkness is desirable. A moist atmosphere may be maintained by placing water near stored

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rubber parts. Apparatus may be kept in suitable racks or in trunks devised for the purpose or even in suitable wooden boxes. Racks may be made of pipe or of 2 by 4 inch lumber, or wooden or metal cupboards may be provided. One mining company has found zinc-lined cupboards very satisfactory. It is recommended that the housing and care of apparatus be placed in the charge of one competent man, who should be held definitely responsible for the periodical examination and the proper working condition of all apparatus. He should examine and thoroughly test all apparatus at least once a month, replacing any worn-out or deteriorated parts. A separate building for storing apparatus is desirable if it can be had. Apparatus should be stored together in one building or room in sets of five or more. It is a dangerous practice to separate sets of apparatus, even though they are in good condition, by placing one or more sets at each shaft collar or mine mouth, as the use of less than five sets of apparatus in mine rescue work is dangerous.

48. This committee has been guided by the belief that the proper testing of apparatus, both for governmental approval and for use at the time of a disaster, is absolutely essential to protect the wearers and to save them from the unfortunate and deplorable deaths that some apparatus wearers have met.

Respectfully submitted.

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REPORT OF SUBCOMMITTEE NO. 3 ON PHYSIOLOGICAL EFFECTS IN USE OF MINE RESCUE APPARATUS AND METHODS FOR DETECTING DANGEROUS GASES.

PHYSIOLOGICAL REQUIREMENTS FOR BREATHING APPARATUS.

49. The following substances and conditions in self-contained breathing apparatus may be important or even vital to men wearing the apparatus:

a. Oxygen in higher concentrations than in atmospheric air at sea level.

b. Carbon dioxide content of the inhaled oxygen being high through failure of the regenerator.

c. Abnormal accumulations of impurities (nitrogen, hydrogen, and argon) in the oxygen.

d. High temperature of the inhaled oxygen.

e. Resistance in the apparatus to respiration.

f. Weight of the apparatus.

OXYGEN IN HIGHER CONCENTRATIONS THAN IN ATMOSPHERIC AIR AT SEA LEVEL.

50. Pure air at sea level, according to Rosenau,[2] contains columetrically 20.94 per cent oxygen, 78.09 per cent nitrogen, 0.94 per cent argon, 0.03 per cent carbon dioxide, and traces of other gases. Expired air contains 16.3 per cent oxygen, 79.32 per cent nitrogen, and 4.38 per cent carbon dioxide. The residual or alveolar air in the lungs contains about 15 or 16 per cent oxygen and between 5 and 6 per cent carbon dioxide when normal atmospheric air at sea level is breathed. Under these circumstances the hemoglobin of the red cells as they leave the lungs is practically saturated with oxygen. The average man breathes 16 to 18 times a minute when at rest, and inhales at every breath 400 to 700 c. c. (24 to 42 cubic inches), or 5 to 13 liters (300 to 780 cubic inches), a minute. However, he only consumes about 300 c. c. (18 cubic inches) of oxygen a minute when at rest, whether breathing oxygen or normal air; but when working hard he may consume 3 liters (180 cubic inches) or more and, under such conditions, may inspire at each breath as much as 2,500 c. c. (150 cubic inches).

51. The oxygen commonly used in self-contained breathing apparatus contains about 2 per cent of other gases, usually argon and

[2] Rosenau, M. J., *Preventive medicine and hygiene*, 1921, p. 662.

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nitrogen; it may contain hydrogen if it is prepared by certain methods. Some of the early observers reported that breathing oxygen irritated the lungs, but this irritation was probably due to oxides of nitrogen being present in the oxygen used. Recently Briggs,[3] after extensive investigations, has said that experience has shown that men not physically fit find bodily work easier when they breathe oxygenated air than when they breathe normal air, but no such difference exists with fit men. Doctor Briggs found, however, that when working under overload even the fittest man derives benefit from breathing air enriched with oxygen.

52. From our own observation and from work done by other investigators, we believe that there are no evil effects from, or objections to, breathing pure or almost pure oxygen at normal pressure for several hours, and that a man derives at least a potential if not actual benefit from breathing oxygen while wearing self-contained breathing apparatus where his physical exertion is likely to be excessive or where he is not in excellent physical condition.

POSSIBLE HIGH PERCENTAGE OF CARBON DIOXIDE IN THE INHALED OXYGEN DUE TO FAILURE OF THE REGENERATOR.

53. Through the failure of the regenerator, as by short circuits or prolonged use, the percentage of carbon dioxide in the inspired oxygen may become very high. Normal atmospheric air contains about 0.03 per cent carbon dioxide. In the worst ventilated theaters, schools, etc., according to Rosenau, the percentage of carbon dioxide does not run above 0.5 per cent. The effects are headache, sweating, dimness of vision, and tremor. In some experiments made at the Bureau of Mines experiment station, Pittsburgh, Pa., it was found that about 2 per cent of carbon dioxide in oxygen produced a slight increase in lung ventilation but no subjective symptoms; 5 per cent in oxygen caused a noticeable increase in lung ventilation but no other signs or symptoms; 7.2 per cent produced a marked increase in lung ventilation and moderate sweating and a slight fullness in the head after mixture had been breathed for 10 minutes; 9 to 10 per cent produced about 300 per cent increase in lung ventilation and the subject complained of frontal headache and was dizzy and sweating at the end of 10 minutes. About 9 per cent of carbon dioxide in oxygen was breathed by some of the subjects for as long as 45 minutes, but the breathing was very laborious and dizziness, headache, and sweating were marked. In fact, to have done any work while breathing this mixture would have been extremely difficult. However, the minds of the subjects remained clear. All the above observations were made with the subjects seated. From these

[3] Briggs, H., Physical exertion, fitness, and breathing; *Jour. Physiol.*, vol. 54, Dec. 7, 1920, p. 292–318.

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data, we can conclude that, although it is possible to breathe 9 to 10 per cent of carbon dioxide in oxygen, any percentage above 5 will cause noticeable effects, and between 2 and 2½ per cent is all that should be permitted in the inspired air of an oxygen breathing apparatus at any time.

ABNORMAL ACCUMULATION OF IMPURITIES (NITROGEN, HYDROGEN, AND ARGON) IN THE OXYGEN.

54. In self-contained breathing apparatus worn by men who are working hard, especially if their lungs and the apparatus were not properly washed out with oxygen before the apparatus was put on, nitrogen, argon, or hydrogen may accumulate to concentrations higher than those usually found in atmospheric air at sea level. Although these gases are inert as far as their action on the body is concerned, enough hydrogen may accumulate to form with the oxygen an explosive mixture; hence oxygen containing hydrogen should never be used in breathing apparatus. All of these gases—nitrogen, hydrogen, and argon—dilute the oxygen and may dilute it enough to cause symptoms of oxygen deficiency. Often these symptoms may appear before a man realizes that the air he is breathing is deficient in oxygen; he may become suddenly weak, lose control of his legs, fall to the floor, and even become unconscious. Usually he is quickly revived, however, if given oxygen at once, but if even a brief period elapses, disturbed breathing, nausea, vomiting, and a throbbing headache may result. To prevent or relieve these symptoms, oxygen should be breathed for several minutes. If, however, the breathing bag of the apparatus and the wearer's lungs and tissues have been washed well with oxygen at the beginning more than 200 liters of the oxygen supplied must be breathed before the oxygen will be diluted enough to cause symptoms of oxygen deficiency, provided the oxygen is at least 98 per cent pure.

HIGH TEMPERATURE OF THE INHALED OXYGEN.

55. If the inspired air from the breathing bag has a high temperature it usually causes discomfort to the mouth and respiratory passages so long as the wearer is in an atmosphere with a temperature of 85° F., wet bulb, or less, and this discomfort may be so strong as to lower his efficiency. When the wearer is in an atmosphere having a high wet-bulb temperature—above 85° or 90° F.—the dissipation of heat from his skin is materially lessened and the dissipation of heat by his lungs, although this is normally small when compared with that of the skin, ceases when the temperature of inspired air is high. These conditions result in heat stroke. According to studies of the effect of high temperatures and humidities, the temperature of the inspired air has but slight effect, other than a feeling of discomfort, so long as it does not exceed 105° to 110°F. This pre-

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suppóses that the body is exposed to a temperature of 85° F., wet bulb, or less.

RESISTANCE IN THE APPARATUS TO RESPIRATION.

56. Respiration resistance in the apparatus may be due to small breathing tubes or other air passages, to the sticking of valves and the freezing or choking of regenerating material. Besides the danger of leaks due to negative pressure during an inhalation, the wearer experiences discomfort and fatigue when breathing against such resistance. Davies, Haldane, and Priestly,[4] after having made investigations, say at first the frequency of respiration is diminished and the carbon dioxide accumulates in the alveoli of the lungs and in the blood; then almost at once the lung ventilation is increased through deeper breathing. In this way a small or moderate resistance to breathing is compensated for automatically. As the resistance increases, the percentage of carbon dioxide in the blood must increase to stimulate the respiration. When the resistance is high the respiration becomes labored; then as fatigue of respiration develops the breathing becomes more shallow and frequent. As a result of shallow breathing the lungs are not well ventilated, and then results an oxygen deficiency in the tissue cells, the effects of which have been described.

WEIGHT OF THE APPARATUS.

57. The weight of a self-contained breathing apparatus is probably the most evident interference with the efficiency of the wearer, yet we have been unable to find published results of studies on the physiological effects of carrying such a weight. The mine rescue apparatus now in use usually weigh between 30 and 40 pounds. The equipment of a soldier in the United States Army weighs 48 pounds. Because these weights are comparable, a few conclusions may be drawn. The Army has carefully studied the distribution of the various parts of the equipment, placing the weight so that there will be the least disturbance in the center of gravity of the soldier, and thus minimizing muscular strain. Even if the weight is properly distributed, the wearer will be under a definite handicap. According to Notter and Firth, the average daily work of a laborer is between 350 and 400 foot-tons. From these figures and from those given for a soldier marching 10 miles, it requires about 60 foot-tons to carry a 40-pound weight, properly distributed, that distance over level country, or about 16 per cent of a laborer's average daily work. In other words, the weight of the apparatus alone is enough to cause a man when wearing apparatus to do about one-sixth less work than when not wearing it. However, all the

[4] Davies, H. W., Haldane, J. S., and Priestly, J. G., the response to respiratory resistance: *Jour. Physiol.*, vol. 53, 1919–20, pp. 60–69.

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effects of the weight of an apparatus should be carefuly investigated in order to determine the best method of distribution as well as the handicap which it causes.

SUMMARY.

58. *a.* Oxygen in high percentages causes no increase in oxidative processes of metabolism in the body.

b. Oxygen in high percentage is not an aid to men who are physically fit except when under excessive physical strain.

c. Oxygen in high percentages aids men who are not physically fit to do more work and with less fatigue.

d. Two per cent of carbon dioxide in oxygen causes only a slight increase in lung ventilation with the subject at rest; 5 per cent causes a noticeable increase; 7 per cent a marked increase; and 9 or 10 per cent makes respiration fatiguing.

e. Nitrogen, argon, and hydrogen have no direct physiological effect but act indirectly by diluting the oxygen.

f. Oxygen deficiency is usually unnoticed by the subject until he begins to lose control of his legs or falls to the floor. If given oxygen at once, the subject suffers no ill effects, but if a brief period intervenes, headache, nausea, etc., may ensue.

g. High temperature of inspired air has only slight effect, other than that of discomfort, so long as it does not exceed 110° F.

h. Resistance to respiration causes an increased ventilation of the lungs, through the accumulation of carbon dioxide, so long as the resistance is low; when the resistance increases the respiration becomes labored; later respiratory fatigue ensues and the breathing becomes more rapid and shallow, causing oxygen deficiency with its symptoms and effects.

i. The distribution of the weight of the apparatus is important in minimizing muscle strain.

j. From calculations it appears that an average man wearing an apparatus weighing 40 pounds might be expected to do about one-sixth less work than without such weight.

METHOD FOR DETERMINATION BY A PHYSICIAN OF THE FITNESS OF MEN FOR THE WEARING OF BREATHING APPARATUS JUST PRIOR TO USE IN SERVICE OR INITIAL TRAINING.

59. In order that wearers of self-contained oxygen-breathing apparatus may have their safety assured and that they may work efficiently, they should, in addition to being well trained in the use of the apparatus, be sound in body, normal in mind, and physically fit. Before any man is allowed to take training, he should be examined by a physician and pronounced in proper physical and mental condition. The following information is suggested as the minimum that should be obtained at such an examination:

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Physician's examination for mine rescue work.

Date _____

Name _____
Nationality _____
Address _____
Employer _____
Occupation _____
Age _____ Weight _____ Height _____
Eyes: Vision, right eye _____ Left eye _____
Must have 20/30 or better in each eye, uncorrected vision.
Hearing: Whispered voice, right ear _____ feet. Left ear _____ feet
Nose: Abnormal _____ Normal _____
Teeth _____
Throat: Normal _____ Abnormal _____
Chest: Normal _____ Abnormal _____
Expansion: Full expiration _____ Full inspiration _____
Lungs: Normal _____ Abnormal _____
Heart: Normal _____ Abnormal _____
Rate: Standing _____ After exercise _____
After 2 minutes' rest _____
Blood pressure: Systolic _____ Diastolic _____
Abdomen: Weak scars of hernia _____
Loss of extremities: Members _____
Nervous or composed _____
Is applicant capable of sustaining strenuous work _____

_____
(Signature.)

_____
(Address.)

DISCUSSION OF REQUIREMENTS.

60. Training should not be given to men under 18 years of age or over 45. Men younger than 21 years or older than 50 should not actively engage in rescue and recovery work while wearing oxygen breathing apparatus.

61. Men should not be recommended for training when they weigh 10 per cent more than or 10 per cent less than the average standard weight. Men under standard average weight are to be preferred to those overweight, and fat or obese men should be rejected.

62. In persons of normal physique, the height, weight, and chest measurements should be as shown in the table below:

Corresponding heights, weights, and chest measurements.

Height.		Weight.	Chest measurement.	
			Expiration.	Mobility.[1]
Feet.	*Inches.*	*Pounds.*	*Inches.*	*Inches.*
5 1/12	64	128	32	2
5 2/12	65	130	32	2
5 3/12	66	132	32½	2
5 4/12	67	134	33	2
5 5/12	68	141	33½	2½
5 6/12	69	148	33½	2½
5 7/12	70	155	34	2½
5 8/12	71	162	34½	2½
6	72	169	34¾	3
6 1/12	73	176	35¼	3
6 2/12	74	183	35¾	3½

[1] U. S. Public Health Service, Regulations, 1920, p. 113.

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63. Although there is no definite limit, broadly speaking, experience has been shown that men 5 feet 4 inches to 5 feet 10 inches tall, and weighing 135 to 170 pounds, and 21 years to 36 years of age are the most satisfactory.

64. The subject must have at least 20/30 uncorrected vision in each eye. He should be placed exactly 20 feet from well-lighted test cards (Snellen's). Each eye should be tested separately, the eye not under test being excluded by holding a card before it. No pressure should be exerted nor should the excluded eye be closed. As soon as the lowest line that the subject can read has been determined, the vision should be recorded as a fraction (20/30), the numerator being the distance in feet at which the test was made—that is, 20 feet—the denominator, the number on the card opposite the last line read by the subject. Subject with less than 20/30 vision in either eye should be rejected.

65. The subject must have perfect hearing in each ear. To determine this both whisper and watch tests are used. The subject stands 20 feet from the examiner. He closes the ear not under examination with his moistened index finger pressed firmly into the external auditory meatus. Then the examiner, facing the back of the subject, exhales and with his residual air whispers numbers, words, or sentences that should be repeated by the subject. The other ear is tested in like manner. If the subject is unable to hear at 20 feet, the examiner approaches until the subject does hear, the distance is recorded in feet. If the distance is less than 20 feet, it is cause for rejection. A quiet room is essential. The watch test may be made with any watch which has been previously tested out on at least five persons, with normal hearing and the distance used as a standard. A loud-ticking watch, as an Ingersoll, is preferable, and, although the ticking is variable, it should be heard about 40 inches. The number of inches at which ticking is heard, when the subject's eyes are closed and his opposite ear occluded, are taken as the numerator and the distance the watch should be heard as the denominator. This should be equivalent to 40/40, otherwise the subject should be rejected.

66. The subject must have solid teeth in front, including the bicuspids, above and below. Fillings or other dental work, if solid, are not a cause for rejection.

67. There should be no acute sores on the nose, lips, or in the mouth, nor should a man with a short bristly mustache be permitted to take active part in wearing self-contained oxygen breathing apparatus in irrespirable air.

68. The chest should be normal in shape and size and the expansion should be 2½ inches or more. The condition of the heart and lungs should be ascertained to be normal; these organs should be given

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special attention; abnormalities in either should be cause for rejection. Schneider's cardiovascular rating, or a modification of the same, should be used.

69. The abdomen and inguinal regions should be examined for weak scars and hernia, active or potential, before a man should be allowed to take part in rescue or recovery work.

70. A man to wear a self-contained oxygen breathing apparatus and actively engage in rescue and recovery work should have good use of both hands and both feet. The loss of two fingers on either hand does not disqualify, provided there is no interference with the functions of the thumb and remaining fingers.

71. In addition to being physically sound, men should be physically fit. Schneider's test, such as used by the Air Service, may be used for the determination of physical fitness. Rescue men should be accustomed to hard work and capable of sustained strenuous exercise.

72. The Schneider tests and rating are given in the table below.

Cardiovascular rating. Schneider.

A. Reclining pulse rate.		B. Pulse rate increase on standing.				
		0-10 beats.	11-18 beats.	19-26 beats.	27-34 beats.	35-42 beats.
Rate	*Points.*	*Points.*	*Points.*	*Points.*	*Points.*	*Points.*
50-60	3	3	3	2	1	0
61-70	3	3	2	1	0	−1
71-80	2	3	2	0	−1	−2
81-90	1	2	1	−1	−2	−3
91-100	0	1	0	−2	−3	−3
101-110	−1	0	−1	−3	−3	−3

C. Standing pulse rate.		D. Pulse rate increase immediately after exercise.				
		0-10 beats.	11-20 beats.	21-30 beats.	31-40 beats.	41-50 beats.
Rate.	*Points.*	*Points.*	*Points.*	*Points.*	*Points.*	*Points.*
60-70	3	3	3	2	1	0
71-80	3	3	2	1	0	0
81-90	2	3	2	1	0	−1
91-100	1	2	1	0	−1	−2
101-110	1	1	0	−1	−2	−3
111-120	0	1	−1	−2	−3	−3
121-130	0	−0	−2	−3	−3	−3
131-140	−1	0	−3	−3	−3	−3

E. Return of pulse rate to standing normal after exercise.		F. Systolic pressure standing compared with reclining.	
Seconds.	*Points.*	*Change in mm.*	*Points.*
0-60	3	Rise of 8 or more	3
61-90	2	Rise of 2-7	2
91-120	1	No rise	1
After 120: 2-10 beats above normal	−0	Fall of 2-5	0
After 120: 11-30 beats above normal	−1	Fall of 6 or more	−1

1. Subject reclines for 5 minutes. Heart recorded as per A. Systolic blood pressure is then taken and recorded as per F.

2. Subject stands at ease for 2 or 3 minutes, pulse recorded as per C; difference recorded as per B. Standing systolic pressure then taken and recorded as per F.

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3. Subject next steps on a chair about 18 inches high five times in 15 seconds, timed by a watch. To make this test uniform, he stands with one foot on the chair at the count "One"; this foot remains on the chair and is not brought to the floor again until after the count "Five." At each count he brings the other foot on the chair and at the count "Down" replaces it on the floor. This should be timed accurately, so that at the 15-second mark both feet are on the floor.

a. Immediately, while the subject stands at ease, his pulse rate is counted for 15 seconds; this count is multiplied by 4 and recorded.

b. Counting is continued in 15-second intervals for 2 minutes, record being made of the counts at 60, 90, and 120 seconds. The data from *a* will be scored by part D of the table by using the difference between this exercise pulse rate and the standing rate. The data in *b* are scored according to part E of the table. Perfect score is 18; 9 or less indicated physically fit.

73. In order that members of the rescue crews may keep physically fit for subsequent shifts—

a. They should not remain longer on one shift than the time necessary to use one charge of oxygen of an apparatus rated for two hours.

b. Bathing facilities, preferably shower baths with hot and cold water, should be available for the men coming off a rescue and recovery shift.

c. Plain well-prepared food, not too rich in sugar and fats, including hot coffee and pure drinking water, should be eaten in moderation. No food should be eaten for one hour before taking active part in rescue and recovery work.

d. Comfortable and clean sleeping quarters should be provided for members of rescue crews.

e. They should not be permitted to undertake a second or subsequent shift until after they have had at least six hours' rest.

f. No member should be permitted to take a second or subsequent shift in irrespirable air without having been examined and found physically fit by a physician or, in the absence of a physician, by the most competent person present versed in the use of self-contained oxygen breathing apparatus.

74. The temperament of the men who undertake rescue and recovery work is very important. Only those known to be cool, courageous, not foolhardy, unexcitable, and willing to take as well as give orders should be chosen. Selection of proper men is the duty of the mine superintendent, the mine rescue instructor (or the most competent man present versed in the use of self-contained oxygen breathing apparatus and rescue and recovery methods), and the physician.

75. Only men of normal mentality should be selected. Mentality should not be confused with education; the ability to understand a situation, draw correct conclusions, and to act with good judgment on those conclusions should determine mentality.

76. All members of mine rescue crews should be able to speak, read, and write the language of the country in which they work—English in the United States.

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77. All members of mine-rescue crews should be thoroughly qualified in first-aid methods.

78. Men to be given training in the use of self-contained oxygen breathing apparatus for mine rescue and recovery should be familiar with mining.

SUMMARY OF CAUSES FOR REJECTION.

79. *a.* Any difficulty in breathing.

b. Defective eyesight.

c. Missing or defective upper or lower teeth, including bicuspids.

d. Respiratory diseases, such as tuberculosis, bronchitis (acute or chronic), or asthma.

e. Any cardiac (heart) disorders.

f. Nervous disorders, such as epilepsy or St. Vitus's dance, or nervous habits.

g. Subnormal mentality.

h. Younger than 18 years of age or over 45 years of age.

i. Ten per cent over or 10 per cent under average normal weight.

j. Intemperance in the use of alcohol or drugs.

k. Special idiosyncrasies, such as being made to vomit by the irritating effects of the mouthpiece, or subject to oxygen-deficiency syncope (fainting in low oxygen), or having a mustache, especially if it be short and bristly.

METHOD FOR DETERMINATION BY CAPTAIN OF RESCUE CREW OF THE FITNESS OF MEN FOR THE WEARING OF BREATHING APPARATUS JUST PRIOR TO USE IN SERVICE.

80. When men are known to be physically sound as shown by examination previously made by a physician, the following test may be used to indicate their present physical fitness.

a. Let the subject sit quietly five minutes or longer; at end of the period count his pulse for a full minute. If the pulse at this time is 100 or more the subject should not be allowed to engage actively in rescue and recovery work while wearing oxygen breathing apparatus in irrespirable air.

b. Next let the subject step on a chair or other object 18 inches high 15 times in 30 seconds. To make the test uniform he should stand with one foot on the chair during the test. He should bring the other foot onto the chair or up to its level 15 times at a uniform rate.

c. After exactly two minutes, during which the subject should rest sitting down, count his pulse. Persons whose pulse returns to normal after having rested two minutes following exercise may be considered physically fit. Those whose pulse does not return to normal after two minutes of rest following the exercise should be rejected.

NOTE.—No one test known can definitely determine physical fitness, but this test will give some indication of the condition of the man.

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PHYSIOLOGICAL EFFECTS OF GASES ENCOUNTERED IN MINES.

81. Mine air may be contaminated by the gases described below or may be depleted of its oxygen, and in consequence its composition may differ from that of normal pure air.

82. *Carbon dioxide*, CO_2, is a product of the decomposition and combustion of organic compounds and a result of the respiration of men and animals. The proportion in mine air is naturally increased by the process of breathing, by the burning of miners' lamps, by fires or explosions, and by blasting. It is rarely found as emanation from rock strata, as in mines at Cripple Creek, Colo., Tintic, Nev., and Alais, France.[5] This gas is an important constituent of black damp, and traces of it are always present in normal air. It has long been used as a measure of the impurity of air, but its importance as such has probably been overemphasized. Although in itself not toxic, its concentration in mine air is sufficent to cause symptoms in man or even unconsciousness and death. One-half of 1 per cent of carbon dioxide in normal air causes a slight and unnoticable increase in the ventilation of the lungs; that is, a man exposed to one-half of 1 per cent of carbon dioxide will breathe a little deeper and a little faster than when in pure air. If there is 2 per cent of carbon dioxide in the air, the lung ventilation will be increased about 50 per cent; if there is 3 per cent, the lung ventilation will be increased about 100 per cent; 5 per cent causes about 300 per cent increase in the lung ventilation and the breathing is laborious; 10 per cent can not be endured for more than a very few minutes. The results are obtained from carbon-dioxide air when the oxygen in the air remains about normal and the subject is not working.[6]

83. *Carbon monoxide*, CO, sometimes but inappropriately called white damp, is a product of incomplete combustion or destructive distillation of organic material. It is produced during mine fires, explosions of gases or coal dust, and in blasting. This gas causes a great many deaths among miners. It is without odor, color, or taste, and its effects often go unnoticed by the victim until too late.

84. The rate of absorption at different percentages of carbon monoxide in air was carefully determined and the symptons carefully observed by Dr. Yandell Henderson,[7] who formulated the following statement to estimate the probable effect (within reasonable limits) of a given concentration of the gas in a given time.

a. When time of exposure in hours times the concentration of carbon monoxide in parts per 10,000 equals 3, there is no perceptible effect.

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[5] Rice, G. S., personal statement.

[6] Hill, Leonard, Science of ventilation and open-air treatment: Special Report Series, No. 52, Medical Research Council, London, 1920.

[7] Haggard, H. W., and Henderson, Yandell, The treatment of carbon monoxide poisoning: Jour. Am. Med. Assoc., vol. 77, Oct. 1, 1921, pp. 1065–1067. Abstr. in Jour. Ind. Hyg., vol. 3, January, 1922, p. 206.

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b. When the result is 6, there is just a perceptible effect.

c. When the result is 9, there will be a headache and nausea.

d. When the result is 15 or more, the effects are dangerous.

85. That carbon monoxide has no directly poisonous action on nerve tissue was demonstrated by exposing growing embryonic chicken brain tissue to high concentrations of the gas.[8] This point has long been disputed and that carbon monoxide in itself is nontoxic to nerve tissue cells now seems to be definitely determined. Its detrimental effect upon nerve tissue is seemingly indicated as being due to anoxemia.

86. Animals without red blood are not affected by carbon monoxide. It has been shown many times that such animals can live in high concentrations without harmful results. Recent experiments at the Bureau of Mines experiment station at Pittsburgh demonstrated that roaches could be kept for several days in an atmosphere of 60 per cent carbon monoxide and 20 per cent oxygen without lessening their activities. The presence of live cockroaches in mines can not be interpreted as evidence that the air is safe for men to breathe. Canaries are overcome by 0.25 per cent of carbon monoxide in 3 to 4½ minutes.[9]

The contrast of these effects on birds and red-blooded animals with the effects on roaches is striking. (See paragraph 110.)

87. *Hydrogen sulphide*, H_2S, called "stink-damp," from its odor, which resembles that of rotten eggs, is usually a product of the decomposition of sulphide minerals in the presence of moisture. It may also be produced by the burning of black powder and other explosives. It has been found, though rarely, issuing with methane from gas blowers or feeders in coal mines. According to Lehmann[10] as little as 0.05 to 0.07 per cent will sometimes cause death after long exposure, and 0.2 per cent is fatal in a very few minutes.

88. In work recently done at the Bureau of Mines experiment station at Pittsburgh[8] canary birds were killed in about a quarter of a minute in 0.07 per cent and overcome in less than 2 minutes in as little as 0.034 per cent; white rats were overcome and killed by exposure to 0.08 per cent in from 5 to 15 minutes.[11]

89. When mixed with seven times its volume of air, hydrogen sulphide is violently explosive.

90. *Methane*, marsh gas, CH_4, also known as light carbureted hydrogen and the principal constituent of fire damp, is a product of

[8] Haggard, H. W., The growth of neuroblast in the presence of carbon monoxide—A demonstration that this gas had no direct toxic action upon nervous tissue. To be published in Am. Jour. Physiol.

[9] Burrell, G. A., Seibert, F. M., and Robertson, I. W., Relative effects of carbon monoxide on small animals: Tech. Paper 62, Bureau of Mines, 1914, p. 7.

[10] Lehmann, K. B., Experimentelle Studien über den Einfluss technisch und hygienisch wichtiger Gase und Dämpfe auf den Organismus. Part 5, Schwefelwasserstoff: Archiv. für Hygiene, Bd. 14, 1892, pp. 135–189.

[11] Sayers, R. R., and others, Toxicity of gases from Mexican and other high-sulphur petroleums and petroleum products: Bull. 231, Bureau of Mines, 1923, Appendix E. (In press.)

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the decomposition of carbonaceous matter with the exclusion of air and in the presence of water. It is one of the characteristic occluded gases of coal and is occasionally found in other than coal-mining operations. Its common occurrence and easy explosibility are responsible for numerous disasters in coal mines. Methane is colorless and odorless, but its common occurrence in old workings of collieries, where the air may be musty from decaying timber and other impurities, has caused many mining men to believe that it has an odor.[12] It may be detected with the safety lamp and the approximate amount present may be determined by the "cap" on the lamp flame.

91. Methane has no physiological effect upon men, but it may accumulate in mine workings to proportions that make an explosive mixture with the oxygen of the air, or, by diluting the air, may cause a man to suffer from oxygen deficiency. Mixtures of air and methane that contain 5.5 to 12.8 per cent methane will explode if ignited.

92. *Ethane* (C_2H_6), *propane* (C_3H_8), *butane* (C_4H_{10}), and other heavier gases belonging to the methane series are components of natural gas, but are not normally found in coal mines. They usually form but a small part of natural gas and, therefore, would probably not be detected except by analysis. When they are found in gas in a mine in amounts of 1 per cent or more, they should suggest leakage from a gas well. As natural gas is sometimes almost pure methane, the failure to find other gases of the series is no proof that there is not leakage from gas wells in the vicinity.

93. *Afterdamp* and *black damp*. Afterdamp is the mixture of gases remaining in a mine after a mine fire or an explosion of fire damp. It consists of carbonic-acid gas, water vapor (quickly condensed), nitrogen, oxygen, carbon monoxide, and sometimes free hydrogen, but usually it consists mainly of carbonic-acid gas and nitrogen, and is therefore irrespirable.

94. *Black damp* is a term generally applied to carbon dioxide. Strictly speaking, black damp is a mixture of nitrogen and carbon dioxide. Average black damp contains 10 to 15 per cent carbon dioxide and 85 to 90 per cent nitrogen. It is formed by mine fires and the explosion of fire damp in mines, and hence forms a part of the afterdamp. It is an atmosphere depleted of oxygen rather than an atmosphere containing an excess of carbon dioxide.

95. The untoward physiological effects of these gases are caused probably by the presence of carbon monoxide, by deficiency of oxygen, or by increased carbon dioxide.

96. *Oxides of nitrogen* are given off when nitroglycerin, blasting gelatin, dynamite, or other high explosives burn rather than explode.

[12] Peele, R., Mining engineers' handbook. New York, 1918, p. 1388, quoting George S. Rice.

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Haldane found that when nitroglycerin exploded the gases of combustion were 63.2 per cent carbon dioxide and 31.6 per cent nitrogen, but when it burned in the presence of its own gases the resultant bases contained 35.9 per cent carbon monoxide and 48.2 per cent nitric oxide (NO). On contact with air nitric oxide immediately oxidizes to nitrogen peroxide with the production of red fumes. Nitrogen peroxide is probably the most irritating of any of the oxides of nitrogen. Its effects on the respiratory passages are not usually manifest until several hours after exposure, when edema and swelling take place. This irritation may be followed by bronchitis or pneumonia.

APPLIANCES AND METHODS FOR THE QUICK DETERMINATION OF GASES ENCOUNTERED IN MINES.

97. Ordinary dry air consists of 20.93 per cent oxygen, 79.04 per cent nitrogen, and 0.03 per cent carbon dioxide by volume. Normal mine air differs in containing a slightly smaller proportion of oxygen, a slightly higher proportion of carbon dioxide and sometimes, in coal mines, a small percentage of methane. In a well-ventilated coal mine the return air will have 0.10 per cent to 0.80 per cent less oxygen than ordinary air and may contain carbon dioxide and methane to a total quantity usually not exceeding 0.6 per cent.

98. Under abnormal conditions, the composition and character of mine air may differ widely from the limits just stated. Occasionally accumulations of carbon dioxide or of methane or of mixtures of the two gases are found in unventilated or incompletely ventilated parts of a mine, although methane is not usually found in metal mines. Also such incompletely ventilated parts of a mine may contain air deficient in oxygen and high in nitrogen; instances have been reported of almost pure nitrogen gas being encountered in metal mines. It has also been found issuing from the strata in certain coal mines in British Columbia.

99. After a mine explosion or during a mine fire the mine atmosphere in places is usually deficient in oxygen and contains a proportion or carbon monoxide dangerous to human life; also following a mine explosion there are likely to be accumulations of methane (CH_4) due to the interruption of mine ventilation and the escape of methane from the coal measures.

A mine rescue or recovery crew is, therefore, interested in determining for its own protection the presence or absence of dangerous quantities of carbon monoxide and methane in the mine air, and in ascertaining whether there is oxygen deficiency sufficient to imperil human life. Carbon dioxide, if present in dangerous amounts, is usually accompanied by oxygen deficiency and after mine explosions is often accompanied by carbon monoxide.

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100. The equipment desirable for a rescue crew to have at hand for the detection of dangerous gases or conditions in mine air includes an approved flame safety-lamp for detecting methane and indicating oxygen deficiency.

DETECTION OF METHANE AND OXYGEN DEFICIENCY WITH THE FLAME SAFETY LAMP.

101. For detecting methane, and possible oxygen deficiency after mine fires and mine explosions, Subcommittee No. 4 recommends an approved type of flame safety lamp as part of the equipment of a rescue crew.

102. A safety lamp is safe only when in proper condition and in the hands of a competent person. Defective or improperly assembled safety lamps have been the cause of serious mine disasters and consequent loss of life.

103. The flame safety lamp should ordinarily be carried and used by the captain of the rescue crew, but each member of the crew should be thoroughly familiar with its construction and assembly and the methods of testing for methane.

104. After the lamp has been thoroughly cleaned, filled, and properly reassembled, test for tightness should be made by blowing against the lower chimney joint. Leakage will be indicated by flickering or wavering of the flame.

105. When a lighted safety lamp is introduced into a mixture of air and methane, the methane coming in contact with the flame is burned and the length of the flame is increased. The increase in length is a fair indication of the percentage of methane present. Three methods of testing for the presence of methane with the flame safety lamp are in use:

a. With an ordinary working flame, or flame used for illuminating purposes;

b. With a somewhat shorter or intermediate flame.

c. With a nonluminous flame.

The latter method is recommended; it is believed to be safest, and with it smaller percentages of methane can be detected.

106. The Mine Inspectors' Institute of America at its recent annual meeting recommended "That tests for gas be made with a nonluminous flame, using a flame safety lamp of one of the types approved by the United States Bureau of Mines and burning fuel also approved by the bureau, for each specific type."

107. In testing for methane with a flame safety lamp care should be taken to hold the lamp vertically and to raise it gently into the atmosphere to be tested. If methane is present, a blue cap will form on the nonluminous flame, the height of the cap indicating approximately the percentage of gas present. When methane is found the lamp should be gently lowered and removed from the air

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containing methane. By the use of the nonluminous flame of a naphtha-burning lamp, as low as 1 per cent of methane may be detected by an experienced person with exceptionally good eyesight.

108. Atmospheres deficient in oxygen are frequently met by apparatus crews exploring mines after explosions or fires and exploring sealed areas underground. In such atmospheres the flame of the safety lamp is extinguished. A flame safety lamp will not burn in a mine atmosphere containing less than 17 per cent oxygen.

109. Members of apparatus crews should carefully study Miners' Circular 12, Bureau of Mines, "The Use and Care of Miners' Safety Lamps," by J. W. Paul. Likewise members of such crews should thoroughly familiarize themselves with the occurrence, properties, and characteristics of mine gases.

DETECTION OF CARBON MONOXIDE AND IRRESPIRABLE ATMOSPHERE WITH CANARIES.

110. A canary in a small portable cage is an almost indespensable adjunct to rescue work after a mine explosion or during a mine fire. The symptoms manifested underground by a canary in the presence of carbon monoxide are an increased rate of breathing, often accompanied by opening of the mouth, fluttering and unsteadiness on perch, and at last—sometimes almost instantly—unconsciousness and death. It is advisable to hold the canary occasionally at least as high as the head, particularly if the person testing is not wearing apparatus, so that the air breathed by the canary will correspond with that in proximity to his nostrils. Canaries also show distress in air markedly deficient in oxygen or high in carbon dioxide (4 to 6 per cent). For further information regarding the effects of carbon monoxide on canaries see Technical Papers 62 and 122 of the United States Bureau of Mines.

IODINE PENTOXIDE INDICATOR.

111. Carbon monoxide in concentrations as low as 0.07 per cent can be detected in a few seconds with an iodine pentoxide detector which contains fuming sulphuric acid and iodine pentoxide on granular pumice in a sealed glass tube. Just before the tube is used its tips are broken; then the tube is connected with a hand syringe by which a measured volume of air, freed from interfering gases, can be passed through the detector tube. A greenish color develops which is proportional to the concentration of the carbon monoxide in the air tested. By comparing this color with the scale an approximate quantitative determination may be made.

MISCELLANEOUS EQUIPMENT.

112. Additional gas-testing equipment useful at times to rescue crews includes the Burrell methane detector for the rapid quantitative

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determination of methane in the mine, the portable Orsat apparatus for the quantitative determination of carbon dioxide, oxygen, carbon monoxide, and methane, and gas-sampling tubes and accessories.

113. The Burrell methane detector when properly used by a person understanding it will give the percentage of methane with a maximum error of 0.15 to 0.30 per cent, according to the amount of methane in the sample. Further details on the use of this instrument may be had by writing to the United States Bureau of Mines, Washington, D. C.

114. The portable Orsat apparatus will give the constituents of mine air with an accuracy of 0.2 to 0.4 per cent. It is particularly useful in making quick determinations of the methane content of mine returns, and in analyzing samples of air from sealed-off areas to determine the advisability of reopening the area. Full description of the Orsat apparatus and instructions on its use are contained in Bulletin 42 of the United States Bureau of Mines.

115. Gas-sampling tubes may be of the glass vacuum-bottle type, or of the water-displacement type. Sample may also be taken by air displacement with an aspirating bulb, particularly if the sample is to be drawn from a pipe leading to a sealed-off area. Whatever type of sampling tube is used, tight sealing of the sample bottom immediately after the sample is taken is essential. The glass vacuum sample bottles are readily sealed with small metal caps filled with prepared wax, the caps being forced firmly over the capillary tips of the bottles immediately after sampling.

116. In taking mine-air samples the sampler should keep in mind the particular conditions on which he desires information. If he is sampling a return airway, he will probably be interested in the total quantity or the percentage of methane in the return air. Samples taken should therefore represent the cross-sectional area of the entry. If, however, he is attempting to determine whether or not explosive gas is present at a face or over a fall, his samples should be taken near the top of the entry or fall in a location corresponding to that where ignition might be caused by a carbide lamp or trolley spark. Detailed suggestions regarding sampling under various conditions can be obtained from the United States Bureau of Mines.

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REPORT OF SUBCOMMITTEE NO. 4 ON THE USE OF MINE RESCUE APPARATUS IN COAL MINES.

117. As coal mines are liable to explosions, fires, and other disasters, it is important to plan an organization in advance of possible disaster and to provide suitable equipment and supplies.

RESCUE TRAINING.

NUMBER OF MEN TRAINED.

118. The minimum number of men trained at a mine should be 10 per cent of the number of men employed at that mine, with an absolute minimum limit of 10 men. As many as possible outside men familiar with the underground workings should be included.

SELECTION OF MEN.

119. In selecting rescue men, considerable care should be used, both as to physical and mental fitness and also as to experience in and familiarity with the underground workings.

HOW TRAINED.

120. The course of training should include a certain amount of underground training, and in every case should be the equivalent of the course prescribed by the United States Bureau of Mines. Additional rescue training should be given at least once a month.

All rescue men should also receive the regular Bureau of Mines first-aid course, and particular stress should be placed on artificial respiration.

A smoke room should be provided in which the apparatus can be tested for tightness and for proper functioning.

SUPERVISION OF RESCUE TRAINING.

121. The training of men in the use of apparatus should be in charge of the superintendent or foreman of a central rescue station, or of a mine official thoroughly familiar with mine rescue work and recovery methods.

EMERGENCY EQUIPMENT AND SUPPLIES.

AMOUNT OF APPARATUS.

122. At an individual mine, a minimum of five sets of approved two-hour apparatus and as many additional units of five sets as the number of men or the extent of the workings warrant should be provided.

Where a central rescue station is maintained for a group of mines, a minimum of 10 sets of approved two-hour apparatus should be maintained.

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APPARATUS ACCESSORIES.

123. The following rescue apparatus accessories are recommended namely:

1 oxygen pump.
6 oxygen tanks, each with a capacity under 120 atmospheres of 600 cubic feet of oxygen at atmospheric pressure, always fully charged and on hand.
60 charges of regenerating material always on hand.
A supply of repair parts for maintaining apparatus and pump in good working condition.

AUXILIARY RESCUE EQUIPMENT.

124. The following auxiliary rescue equipment and supplies are recommended:

Safety lamps (approved types).
Electric cap lamps (approved types) and charging arrangement for them.
Carbon monoxide detector.
Stretchers.
Life line (1,000 feet long).
Chalk.
Electric flashlights.
Brattice cloth.
Brattice boards.
Nails.
Tools, including copper hammers.
Mine telephones and wire.
Unlined linen fire hose.
Fire extinguishers.
1,000 feet of §-inch nontwisting hoisting rope.
Iron bucket large enough to lower four men.
(The last two items are recommended for shaft mines only.

MINE MAPS.

125. Six copies of the mine map showing the last extensions and the date on which extensions were made should be kept with the rescue apparatus. These maps should show the sections in which men are working as well as the following data: Details of ventilation, water lines, air lines, electric lines, doors, overcasts, refuge chambers, first-aid stations, underground stables, pumps, hoists, substations old workings, gaseous sections, traveling ways, sealed-off areas, rock-dust barriers, stone-dust areas, sumps, tunnels, escapeways, elevations, haulage ways, etc.

PROCEDURE FOLLOWING EXPLOSIONS OR DANGEROUS FIRES.

WHOM TO NOTIFY.

126. Notify all cooperative agencies, such as the State inspection department, the United States Bureau of Mines, and privately owned rescue stations. Also notify doctors.

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SELECTION OF MAN TO ASSUME CHARGE, AND DUTIES.

127. Select a responsible man to assume complete charge, who shall see that the following important steps are carried out:

a. Assemble needed apparatus men from list of names and addresses of trained men; this should always be kept available.

b. Assemble men for handling supplies.

c. Select responsible and experienced men for taking charge of rescue work, who will select captains and rescue crews.

d. Subject all rescue men to rigid physical examination.

e. Adopt some definite plan of procedure.

f. Keep the fan or other ventilating appliances in operation if the violence of the explosion has not destroyed them. The advisability of reversing the ventilating current is a matter of great importance; it requires a knowledge of the conditions within the mine and the course of the ventilating currents prior to the explosion. The ventilating current should not be reversed without good reason, and the desirability of reversing the current depends entirely on local conditions, the plan of ventilation, and the direction of the current on the main haulage roads and manways. At every reversible mine fan a notice should be posted to the effect that the fan should not be reversed except by authority from the person in charge of the mine.

g. Disconnect all electric wires leading into the mine except telephone lines and shaft signal wires, if these are intact where observable and if there is a possibility of live men signaling.

h. Rope off an inclosure about the mine entrance and post guards to prevent unauthorized persons from entering the inclosure.

i. Establish a proper system for checking the men in and out of the mine, a system that will give the name of the man and the hour of entering and leaving.

j. Establish headquarters for rescue apparatus and crews.

k. Provide food and sleeping quarters for rescue crews.

DUTIES OF CAPTAIN AND MEMBERS OF EACH CREW.

128. The captain is to receive instructions, from the one in authority, as to where and how far to go, and as to the work he is expected to perform, and the captain should in no case exceed these instructions. Should conditions be found that in his judgment make it unsafe for him to carry out his instructions to the letter, he is to perform only that portion which can be done with reasonable safety to himself and crew.

129. Before the crew enters on its trip, the captain should explain to its members the purpose of the trip and what he expects each member to do. He should also carry a small pad of paper and a pencil with which he may write any particular instructions that he may deem necessary to his men. All attempts to talk while wearing apparatus should be discouraged as much as possible. A small horn may be attached to the captain's apparatus; with it he may sound any one of a prearranged code of signals and thus call his men to halt, proceed, or retreat, as the case may be.

130. Before starting on a trip in an irrespirable atmosphere the captain of the advance crew should make sure that an emergency

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crew is ready at the fresh-air base, and should also assure himself that his own crew has an adequate supply of oxygen and that the apparatus of each member is functioning properly.

CONDITIONS UNDER WHICH BREATHING APPARATUS MAY BE USED IN ENTERING AND EXPLORING MINES.

WHEN NOT TO MAKE EXPLORATION TRIPS.

131. In general, explorations in irrespirable atmospheres in coal mines should be undertaken only when conditions are such that the exploration may be done with reasonable safety to the crew. Exploration trips should not be undertaken under the following conditions:

a. In dense smoke, except with life line and then only to save life, to turn valves, or to shut or close doors essential to recovery operations.

b. When an explosion from dangerous accumulations of gas is probable.

c. When crawling on hands and knees is necessary because of low roof, slate falls, or other obstructions.

d. When it is necessary to wade in water more than knee deep.

e. In dangerously high temperature with high humidity.

f. With less than a full crew of five men.

g. With apparatus not adequately charged or not in perfect condition.

h. Unless there is a reserve crew, fully equipped, at the fresh-air base (except for very short trips).

APPLICATION OF TESTS OF BREATHING APPARATUS SUITABLE TO THAT APPARATUS IN ACCORDANCE WITH SPECIFICATIONS LAID DOWN BY SUBCOMMITTEE NO. 2.

TESTING APPARATUS.

132. Immediately before use all apparatus should be tested for tightness and proper functioning, as recommended by Subcommittee No. 2.

TESTING OF PHYSIOLOGICAL CONDITION OF MEN UNDER PROVISIONS LAID DOWN BY SUBCOMMITTEE NO. 3.

PHYSICAL EXAMINATION.

133. All rescue men should be given physical examination, as laid down by Subcommittee No. 3, immediately before beginning rescue operations and as often thereafter as may be deemed necessary by the attending physician.

PROCEDURE IN ENTERING MINES BY SHAFTS, BY SLOPES, AND BY DRIFTS.

FRESH-AIR BASE AND METHOD OF COMMUNICATING WITH IT.

134. After the fan has been started and ventilation thereby partly restored a suitable fresh-air base should be established. As soon as this has been done a means of communication should be established

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with the outside, preferably by mine telephone. If for any reason the location of the fresh-air base or the direction of the air currents has to be changed and in consequence it becomes possible for an explosive mixture of gas to come in contact with the telephone and wires, the telephones should be removed and the wires either disconnected outside the danger zone or removed entirely.

PROCEDURE OF CREWS TO FRESH-AIR BASE.

135. When the advance and the reserve crews and the man in charge of rescue operations proceed to the fresh-air base, if the distance to be traveled by the crews is long, or the traveling road difficult, the apparatus should be carried in by men other than the rescue crews.

EQUIPMENT OF CREWS.

136. It is desirable that the members of each crew be equipped with the same type of apparatus. In addition to his two-hour apparatus, each member should have goggles and approved electric lamps or flashlights. The advance crew should be equipped with a carbon-monoxide detector or a canary bird, one flame safety-lamp of approved type, and chalk for marking directions of travel.

At the fresh-air base there should be the following equipment: Life line, resuscitator, stretchers, blankets, first-aid cabinet, extra oxygen bottles, chemical fire extinguishers, and repair parts for apparatus.

The fresh-air crews should see to bringing up and maintaining ample supplies of canvas, brattice boards, nails, tools, etc., at the fresh-air base.

EXPLORATION PROCEDURE.

137. The captain and members of the crew should first examine the apparatus for tightness and proper functioning; they should also make sure that their supply of oxygen is adequate, and that all valves controlling oxygen flow, other than automatic pressure valves, are locked and in proper condition.

A life line should be used if the crew is unfamiliar with the territory to be traversed, or if one or more turns are to be made, or if vision is obscured by smoke.

MANNER OF PROCEDURE.

138. The crew should proceed carefully in single file, with a 6-foot interval between the members of the crew.

Examine roof and roadway.

Mark with chalk the direction of the course taken, arrows pointing to the fresh-air base, and mark the farthest extent of the exploration trip.

Carefully observe conditions and report them to the man in charge upon return to the fresh-air base.

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MAXIMUM DISTANCE TO BE TRAVELED UNDER OXYGEN IN IRRESPIRABLE ATMOSPHERES.

FLAT SEAMS—DISTANCE TO TRAVEL.

139. (By a flat seam is meant one with a dip or rise not exceeding 1 foot in 10.)

With a crew in proper physical condition and a reserve crew wearing apparatus at the fresh-air base, explorations of not to exceed 1,000 feet (2,000 feet round trip) in irrespirable gases may be made if necessary, provided conditions are favorable. By favorable conditions are meant a nearly level, unobstructed course, height of 5 feet or more, good roof, air clear, or so nearly clear that vision of the rescue crews is not materially obscured.

PITCHING SEAMS—DISTANCE TO TRAVEL.

140. (By a pitching seam is meant any seam that dips or rises more than 1 foot in 10.)

The maximum distance of 1,000 feet recommended for seams with pitches up to 1 foot in 10 should be reduced proportionately as the pitch increases. Exploration should never be undertaken on pitches in excess of 30 degrees unless there is reasonable assurance of saving life; and exploration should never extend beyond the first breakthrough until ventilation has been advanced to that point.

ROBERT MEDILL, *chairman*, *Springfield*, *Ill.*
C. A. HERBERT, *secretary*, *Vincennes*, *Ind.*

For flat coal beds:

E. H. DENNY, *Pittsburgh*, *Pa.*
ROBERT LILLY, *West Virginia.*

For pitching beds:

J. J. FORBES, *Birmingham*, *Ala.*
J. J. COREY, *Coos Bay*, *Oreg.*

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REPORT OF SUBCOMMITTEE NO. 5 ON REGULATIONS FOR USE OF MINE RESCUE APPARATUS IN METAL MINES.

141. To meet the emergencies that may arise when a mine fire starts or a body of irrespirable gas intrudes into the workings of a mine, some well-defined degree of preparation is necessary. This preparation consists of providing a definite amount of equipment and facilities for storing and transporting it and also such organization of personnel for emergency duty as circumstances and surrounding conditions may warrant.

The equipment required will consist of enough breathing apparatus for two crews of 5 men each, supplies to maintain the apparatus in use for additional periods of several days, and certain auxiliaries for the use of the crews. These auxiliaries become the working tools of the crews and are essential for safe and efficient work.

142. Each mine should possess equipment or be allied with some other mine or central station within an hour's travel that maintains equipment. The equipment will consist of modern approved two-hour breathing apparatus, an oxygen supply in gaseous, liquid or chemical form, and regenerators; auxiliaries may consist of half-hour apparatus, portable electric lamps, stretchers, saws, pick-axes, life line, first-aid material, tools for repair of apparatus, portable fans, etc.

143. All apparatus and auxiliary equipment when not in use shall be properly housed in the manner designated by subcommittee No. 2. In general, the apparatus should be protected from deterioration and kept assembled in working order, and, to insure this, its supervision must be definitely the duty of some one man who should test it at least monthly in accordance with the test requirements laid down by subcommittee No. 2.

SURFACE PREPARATIONS PRIOR TO DISASTER.

144. The mine officials (surface and underground) should form an organization for fire fighting and fire prevention; in this organization fire-prevention measures and possible fires should be fully discussed with probable action taken to prevent spread of fires. The most suitable person or persons to take charge of fire fighting should be agreed upon definitely and desirable fire-prevention and fire-fighting methods and equipment should be planned and provided. At every mine at least five persons (preferably 10 or more) trained in the use of up-to-date oxygen-breathing apparatus should be avail-

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able. These men should be selected because of their physical and mental fitness, their familiarity with the mine workings, and their reliability in an emergency. The mine officials, if physically capable, should be among those trained in the use of the apparatus, and at any rate these officials should be familiar with the use of the apparatus and its limitations.

145. There should be available and kept up to date and on file at the mine office a list of the things to be done by various persons in case of fire in the mine; also a list with phone and residence addresses of persons to be notified immediately on the outbreak of a fire, this list to include mine officials, State inspectors, safety men, doctors, ambulances, electricians, officials of intersecting mines, etc. It is also advisable to have on record the mine rescue and similar equipment and the personnel of apparatus wearers of neighboring mines.

146. At points giving maximum publicity should be posted regulations regarding surface and underground fires, and up-to-date maps of mine workings shoud be kept available, these maps showing direction of air currents, location of fans, air splits, doors, water and air lines, hoists, and other machinery, besides indicating, so far as possible, the inaccessible parts of the mine.

147. One of the most essential devices for the control of mine fires and the protection of apparatus men and other mine-fire workers is a mechanically driven surface fan equipped to permit quick reversal of air currents. Among other equipment that should be available at the surface at time of fire are telephones, portable fans, flexible tubing, fire extinguishers, fire hose and fittings, and supply of canvas, boards, nails, etc., for bratticing.

UNDERGROUND PREPARATIONS PRIOR TO DISASTER.

148. In addition to being a part of the general fire-fighting organization of the mine, as heretofore outlined, underground officials of mines should be able to wear apparatus and should provide such equipment and conditions as will enable apparatus wearers to work in greatest safety and to best advantage. Among the measures that may be taken are these:

a. Divide the mine into separate air splits by means of suitable doors and other ventilating devices.

b. Place at each shaft station a suitable list of hoist signals and the designation of that station.

c. Keep suitable exit signs, or signs designating names of drifts, crosscuts, chutes, etc., in place and in good condition.

d. Provide, in so far as may be feasible, that there will be no change of conditions underground while apparatus men are working.

e. Have available, in good condition, a supply of first-aid materials, stretchers, etc., as well as men able to give first aid, especially artificial respiration.

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149. Among the methods and equipment that may be adopted for preventing mine fires are these:

a. Guniting.
b. Adequate water lines and plenty of available hose, nozzles, etc.
c. Having at strategic places fire extinguishers in workable condition.
d. Having fire doors in working order, etc.
e. Providing emergency shaft signals and especially signals operable from moving cage.
f. Installing stench warning for miners.
g. Placing of telephone system at shaft stations or near mine workings.
h. Establishing underground refuge places.

SURFACE ACTIVITIES AT TIME OF DISASTER.

150. The first duty at the time of a mine fire is to remove underground workers as promptly as possible; next in importance is the immediate notification of interested persons and organizations, including company officials, State inspectors, apparatus wearers, safety engineers, doctors, ambulances, and adjoining mines—the latter especially if the mines have intersecting workings.

151. Some one person should take charge of all activities at the mine and, at least for a time, all matters should be referred to him for judgment. Later he should delegate to others certain definite duties, but it is very important one central authority should correlate all activities, thus avoiding dangerous confusion through conflicting orders and duplication of work.

152. As soon as possible after a diaster, measures should be taken to exclude from mine workings any and all persons except those authorized to enter for specific purposes. A system of checking all persons into and out of the mine should be established; the name of each person entering, the exact time of his entrance, the estimated time he is to be underground, the part of mine he is to enter, and the exact time he leaves the mine should be recorded. All persons should be required to comply with this arrangement. Mine shafts or entrances, hoisting engines, fans, rescue-apparatus headquarters, field hospitals, and similar important places, where the presence of visitors would interfere with good work, should be roped off and guards posted to prevent unauthorized persons from entering the inclosures.

153. On the arrival of apparatus wearers, provision should be made to examine them physically to determine their fitness for the work, this examination to be under the requirements laid down by subcommittee No. 3. The testing of apparatus (under the requirements laid down by subcommittee No. 2), the assembling of crews, and all matters pertaining to the apparatus should be placed in the control of one man who has thorough knowledge of the apparatus and its limitations. The best qualified apparatus man can generally

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give by far the best service if he is held to this work instead of being permitted to go underground with crews. There should be no exploration with apparatus until a full crew of five men, thoroughly acquainted with the apparatus, has been assembled, the apparatus thoroughly tested, and, if possible, until each member of the crew has been found to be in proper condition. In general, it is advisable to withhold such explorations until a reserve crew with reserve apparatus is available.

154. As soon as possible a definite place should be designated for storing, assembling, and repairing apparatus. At this place an adequate supply of repair parts, oxygen, regenerators, etc., should be available. Provision should also be made to feed apparatus men and other workers, especially to have hot coffee or tea, sandwiches, etc., available at practically all times. Usually, also provision will have to be made for sleeping accommodations for apparatus men and other workers and some cots at least should be at or near the mine opening for the use of workers who may become ill during the rescue and recovery work. If heavy loss of life is probable, a morgue should be established, probably with suitable arrangements made for identification of bodies and at least preliminary measures taken for preparation for burial.

155. As soon as possible after the discovery of fire or a mine explosion steps should be taken to assemble at some convenient point and to place in good condition stretchers, blankets, first-aid materials, flash lights and batteries, portable fans, flexible or other fan tubing, fire hose, etc.; also to assemble such material as nails, hammers, saws, lumber, pipe, and similar articles likely to be needed in restoring ventilation, bratticing, etc. It would also be advisable to assemble some mice, canary birds, or mechanical gas detectors, for use in testing air upon entering the mine, and especially in establishing fresh-air bases.

ACTIVITIES UNDERGROUND AT TIME OF DISASTER.

PRELIMINARY EXPLORATION AND ESTABLISHMENT OF FRESH-AIR BASES.

156. The first duty of underground employees on the discovery of fire is to warn other workers and aid them to escape. As soon as all available men have been removed from the mine immediate measures should be taken to prevent loss of life in fire fighting or recovery work; one of the first steps should be to exclude from the mine all relatives of possible victims, and to allow only those to enter who can be expected to work dispassionately. If haulage or signaling devices have been destroyed or deranged, especially if in a shaft, these should be restored before apparatus work is attempted.

157. In making the first exploration with apparatus after a

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fire extreme precaution should be taken and progress should be slow. It would be advisable to test the quality of the air, using mice, birds, or possibly a mechanical detector to warn of CO gas and the lamp flame to determine oxygen sufficiency; then if the air is good for some distance into the mine, one of the first duties may be the establishment of a fresh-air base underground.

158. A fresh-air base should be established when air and other conditions indicate its establishment will be safe and will facilitate the work. Care should be taken, however, not to have the fresh-air base so close to a fire that nonwearers of apparatus are made ill from small quantities of gas nor to have the base subject to change because of a possible outflow of gases cutting off retreat. The base should be supplied with repair and extra parts for apparatus and equipment, also with first-aid materials, stretchers, extra supply of oxygen as a protection to the attendant (who should be on hand always while apparatus men are at work), a mouse or canary, and a flame lamp to give warning of an outflow of gas. As exploration work progresses, the fresh-air base should be moved forward, but with full precaution taken to protect the retreat of those at the fresh-air base.

NATURE OF UNDERGROUND ORGANIZATION OF APPARATUS CREWS.

159. The predominating thought of the members of a rescue crew should be precaution for their own safety, since without precaution they will be of little value in rescuing others.

160. Men of impulsive or excitable nature should not be members of a rescue crew; their spasmodic actions may disorganize the crew or may cost them their own lives.

161. The energy of each member of a crew that may be called on to make explorations should be conserved for the special work to be undertaken and should not be impaired or exhausted by physical labor in getting to the fresh-air base.

162. When the fresh-air base is more than 500 feet from the mine entrance or shaft landing, the apparatus and portable equipment should be transported by men other than those composing the rescue crew.

163. Apparatus should be cleaned, repaired, assembled, and tested on the surface, and, as heretofore indicated, the apparatus crew should be assembled on and in large measure directed from the surface. All this work should be in the hands of a person thoroughly familiar with apparatus and its use, who should, in general, remain on the surface but take occasional short underground trips to become familiar with conditions at fresh-air bases and at points where apparatus is being used.

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164. Having arrived at the fresh-air base, the captain of the crew shall be in full command. The reserve crew shall take a position at the fresh-air base with apparatus on.

165. A written memorandum should be made by the captain of the advance crew and left with the captain of the reserve crew. This memorandum shall show what part or parts of the mine the crew will explore, the approximate distance to be traveled, nature of the work to be done, and the time that will elapse before return to the base.

166. Immediately before leaving the fresh-air base the apparatus should be thoroughly inspected; if full supply of oxygen is not present or if there is any defect in the apparatus, or if any member of the crew is ill or manifests undue nervousness, the trip should not be taken until the defective condition is remedied.

167. The members of a crew should travel with an interval of two paces at a slow rate, to be determined by the captain, and at no time should the crew separate.

168. In penetrating a smoky atmosphere and when exploring stopes or workings with many intersections, a crew should use a life line, which each member of the crew should hold by his hand.

169. A code of signaling should be adopted for the control of the crew and each member should have a signaling device. There should be no unnecessary talking during explorations with apparatus.

170. Before leaving the fresh-air base the captain shall make a memorandum of the condition of each apparatus, noting the charge of oxygen and its duration; and while away from the base he shall make a similar record at least every 20 minutes.

171. If, at any time while beyond the fresh-air base, any member of the crew becomes distressed or finds his apparatus working improperly, the entire crew shall return with him to the base.

172. If a crew has to climb ladders, a rope of a length approximating the height of climb should be provided for use in case a member of the crew becomes ill while climbing.

173. It is dangerous to make an exploration with less than five men in a crew and, in general, a crew should consist of five men—no more and no fewer.

174. The captain of the crew should be in full charge and his decision should govern. His instructions should come from the persons directing the apparatus work and when he has completed a trip the captain should report to the person who gave him his instructions. In general, specific instructions as to length of trip, exact route, and approximate consumption of time should be given the captain of the crew and, in so far as feasible, no deviation should be made from instructions.

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NATURE OF WORK TO BE PERFORMED BY APPARATUS CREWS.

175. In general, apparatus crews are expected to search for possible live men and to effect the safe removal of any found. Consequently the crews have to transport unconscious men in cars, on stretchers, or otherwise through noxious fumes, and it may be advisable to place on these men oxygen apparatus, the half-hour type being applicable for this purpose. Frequently apparatus is used to ascertain the exact location of fires, and then the wearers should not take the risks they might take where life is involved. Similarly, apparatus is employed to construct air locks, build brattices, doors, stoppings, bulkheads, etc., in mine-fire and recovery work or to restore ventilation; in such work it is not advisable to take undue risks.

176. The use of oxygen breathing apparatus to recover bodies is not good practice because it is usually possible to restore ventilation, after which the handling of bodies is much more readily and safely done than with apparatus. It is especially poor policy to attempt to use apparatus in removing bodies from stopes, raises, or winzes where transportation must be by ladderways. Here ventilation should be restored if possible before removal of the bodies is attempted.

MAXIMUM DISTANCE APPARATUS WEARERS SHOULD TRAVEL.

(This will be given for clear atmosphere under various conditions and subsequently the modifications to be made when the atmosphere is smoky or when high temperature and humidity are encountered.)

177. When the atmosphere is clear but gaseous and the dip is less than 10°, the maximum distance to be traveled by apparatus wearers on unobstructed traveling should be 1,000 feet on advance and an equal distance in retreat. Where falls or other obstructions intervene, the allowable distance may be restricted to a few hundred feet each way, or even less, depending on the dangers due to the falls or obstructions. If water is encountered, it is dangerous to go, even along a level road where the water is much over 1 foot deep, for distances of 100 feet or over.

178. Where the dip is more than 10° and less than about 25° and travel must be undertaken on the floor rather than on ladders or stairways, apparatus trips of over 500 feet each way are dangerous even in clear cool atmosphere, especially if the floor is smooth. Where obstructions are present, distances even shorter than 500 feet are dangerous. When the dip is over 25°, no apparatus trips should be attempted except on ladders or stairs.

179. On inclined ladders (dip up to 60°), where the ladders are in good condition and there are no obstructions (such as close platforms, sollars, walls, timbers, or falls), distances up to 200 feet are permissible in clear air, though if an apparatus wearer becomes helpless

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his safe removal from 200 feet of ladderway is difficult. Where obstructions such as close platforms, the timbers or rock falls intervene in ladderways up to 60°, even shorter explorations with apparatus should not be attempted.

180. On ladders sloping 60° to 90°, explorations with apparatus should not be atttempted, even though the circumstances as to clearness of atmosphere, obstructions, condition of ladders, etc., are favorable except in emergency. In explorations under such emergency, a rope should always be at hand to be used in handling any member of the crew who may become ill or otherwise disabled. Under no circumstances should apparatus wearers climb over 200 feet of ladder at 60° to 90° and, in general, 100 feet should be considered the maximum.

IN SMOKY ATMOSPHERE.

181. In dense smoke apparatus wearers should travel not more than a few hundred feet, even if no obstructions intervene; and to protect each apparatus wearer from falling into holes he should have a cane or staff with which to feel his way. Similarly, travel in dense smoke on a dip over 10°, whether on the floor or on a ladder or stairway, obstructed or unobstructed, should be restricted to short distances, preferably under 100 feet. The life line should always be used when exploring in smoky atmosphere. Goggles may be used to advantage in both clear and slightly smoky atmosphere. Several methods are available to prevent fogging, the simplest being to hold inside the goggle a little water to be run over the interior of the glass when it fogs.

182. Where the atmosphere temperature is above 85° F. and the humidity above 90 per cent there will be further limitation of the allowable distances to be traveled by apparatus wearers, the limitation increasing with higher temperature and humidity, and being intensified if the surrounding air or gases have no movement.

TYPES OF APPARATUS TO BE WORN.

183. The above recommendations apply to the approved types of two-hour oxygen apparatus, as presented by subcommittee No. 2. Half-hour apparatus provided with reducing valve or with automatic oxygen feed should be used cautiously and only for very short explorations and by persons very familiar with apparatus. Masks that remove poisonous gases but can not supply oxygen can probably be used to advantage underground under certain known conditions. However, to introduce them underground is dangerous because of probability that their use will not be confined to suitable conditions but may be applied to all kinds of disaster work, in which event they will most certainly cause fatalities.

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The use of these masks underground is not recommended until such time as the International Conference may see fit to approve them.

CONCLUSION.

This report does not represent wholly the individual opinions of each member of subcommittee No. 5 but is a compromise. The guiding thought in making these recommendations is that all apparatus work should be done with the idea of preventing loss of life of apparatus wearers at all times and under all circumstances.

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APPENDIX.

Addresses and papers given before the conference in the order named:

Purposes of the conference, address by George S. Rice, chief mining engineer, U. S. Bureau of Mines, and presiding officer.

Organization of rescue work and fire fighting, with emphasis on preliminary preparation, address by H. Foster Bain, Director U. S. Bureau of Mines.

History of development of mine rescue apparatus, by J. W. Paul, chief, coal-mine investigations, U. S. Bureau of Mines.

Discussion of development of mine rescue apparatus, by G. S. McCaa, mine safety engineer, in charge of testing rescue apparatus, U. S. Bureau of Mines.

The need of standardization in mine rescue work, the Hon. William Sloan, minister of mines of British Columbia, Victoria, B. C.

Discussion of standardization in mine rescue work, by Daniel Harrington, supervising mining engineer, U. S. Bureau of Mines, Denver, Colo.

Mine rescue work from the viewpoint of the State inspector, by C. A. Allen, chief mine inspector of Utah, Salt Lake City, Utah.

Mine rescue work from the viewpoint of the mine operator, by A. J. Moorshead, president Madison Coal Corporation, Chicago, Ill.

Discussion of mine rescue work from the viewpoint of the mine operator, by Orr Woodburn, director Globe-Miami District Mine Rescue and First Aid Association.

Physiological effects due to use of mine rescue apparatus in mine rescue work, by R. R. Sayers, U. S. Public Health Service, and chief surgeon, U. S. Bureau of Mines.

Discussion of above subject, opened by Dr. A. F. Knoefel, Terre Haute, Ind.

Mine rescue work of the United States Bureau of Mines, by D. J. Parker, Chief, Division of Mine Rescue Cars and Stations, U. S. Bureau of Mines.

Breathing apparatus in fire-fighting and mine recovery work, by H. J. Rahilly, mining engineer, Anaconda Copper Mining Co., Butte, Mont.

Discussion by A. C. Watts, chief engineer, Utah Fuel Co., Salt Lake City, Utah.

Can present mine rescue methods be improved? by George S. Rice, chief mining engineer, U. S. Bureau of Mines.

Organization of mine rescue work and fire fighting in Great Britain—Government requirements for apparatus and limitations of standardization, by Lieut. Col. J. A. S. Ritson, D. S. C., M. C., department of mines, Great Britain.

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